MODEL 272

CAPACITANCE BRIDGE

Instruction Manual

SEPTEMBER 1970

MP MASTER
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Electro Scientific Industries
13900 N.W. SCIENCE PARK DRIVE • PORTLAND, OREGON 97229

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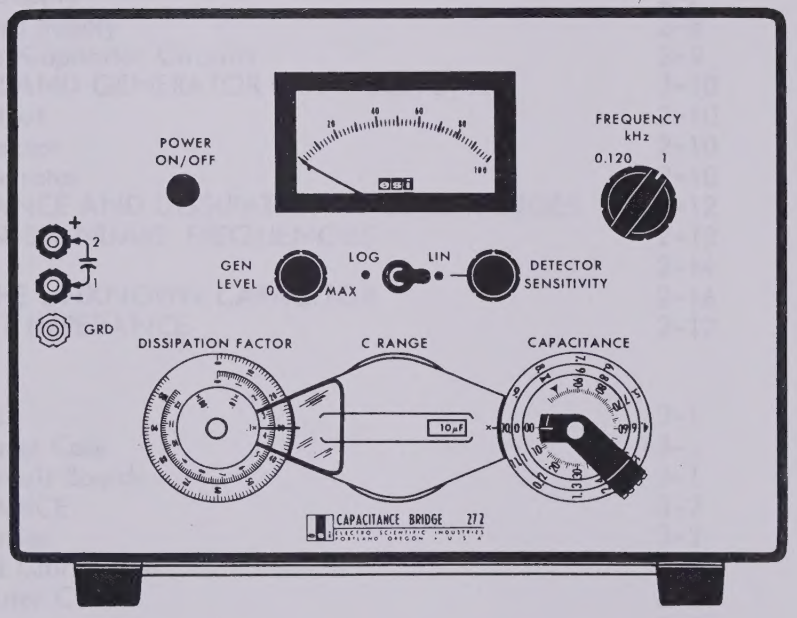

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SERIAL NUMBER: _____

PART NUMBER: 20355

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The following table lists the most recent revision of each page at the present printing:

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SECTION I

INTRODUCTION

1.1 DESCRIPTION

ESI Model 272 Capacitance Bridge is a complete self-contained capacitance measuring system. It is designed for two- and three- terminal measurements of capacitors from 0.01 pF to 120 microfarads.

The bridge has internal shielding and guarding to eliminate effects of stray capacitance in parallel with the unknown. The instrument includes a low-voltage generator and a high-sensitivity detector tuned to 1 kHz or 120 Hz (three additional frequencies available), the frequency being selected with a front-panel switch.

Rear-panel connections allow the use of external ac generators, bias supplies, and detector output.

Figure 1-1 is a simplified schematic diagram of the instrument.

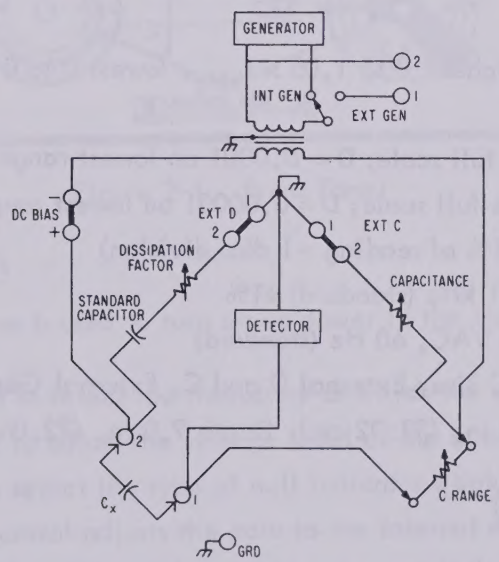


Figure 1-1. Simplified Schematic Diagram

1.2 SPECIFICATIONS

CAPACITANCE

Number of Ranges: 7; highest 0 to 120 μF, lowest 0 to 120 pF

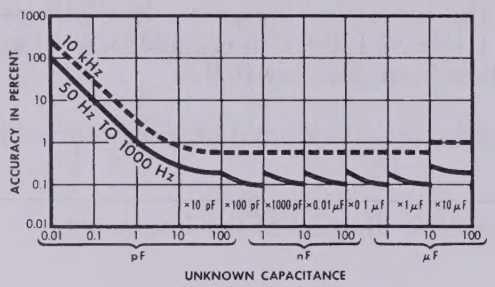
Dial Resolution: 12,105 divisions full scale, 0.01 pF/division on lowest range

Accuracy*

120 pF range: ±(0.2% + 1 dial division)

1.2 nF -12 μF range: ±(0.1% +1 dial division)

120 μF range: ±(0.2% +1 dial division)



DISSIPATION FACTOR

Number of Ranges: 3; highest 0 to 1.05 x f_{kHz}, lowest 0 to 0.0105 x f_{kHz}

Dial Resolution

1 kHz: 105 divisions full scale; D = 0.0001 on lowest range

120 Hz: 125 divisions full scale; D = 0.00001 on lowest range

Accuracy*: ±(0.0005 +1% of reading +1 dial division)

Frequency: 120 Hz and 1 kHz (standard) ±1%

Power Requirements: 115 VAC, 60 Hz (standard)

Auxiliary Terminals: DC Bias, External D and C, External Generator and Detector

Dimensions: Width 13.0 in. (33.02 cm), Depth 9.0 in. (22.06 cm), Height 10.0 in. (25.4 cm)

Weight: 17 lbs (7.70 kg)

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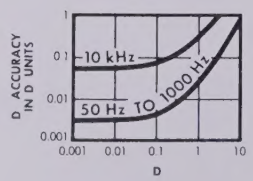
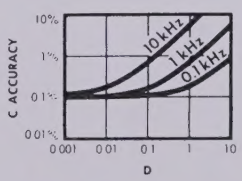
*All accuracy specifications given for test frequency of 120 Hz - 1 kHz at 23°C and D = 0.1 or less. Accuracy at other frequencies and higher D are shown in the following graphs. See also page 2-13.





SECTION II
OPERATION

2.1 CONTROLS

Nearly all of the controls necessary to operate the Model 272 Capacitance Bridge are on the front panel. A few controls, not normally needed, are on the rear panel.

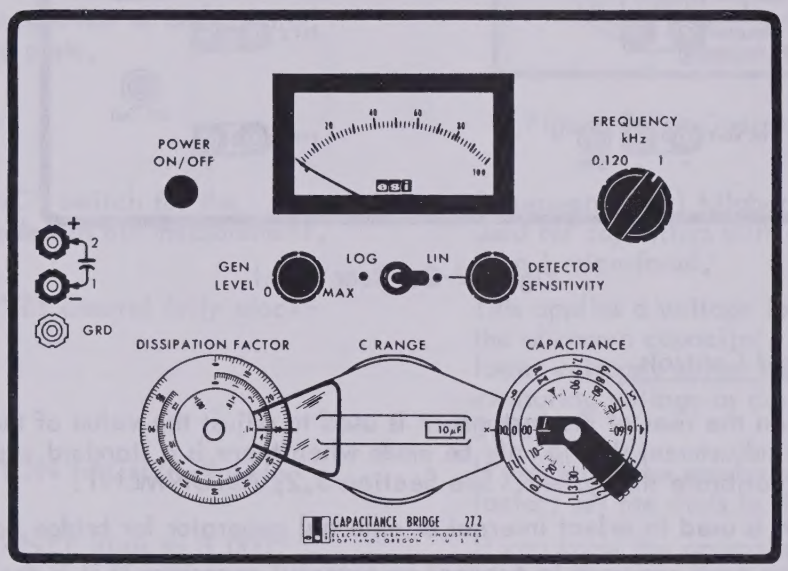


Figure 2-1. Front Panel

2.1.1 Front Panel Controls

POWER ON/OFF pushbutton is used to turn on ac power to the instrument. It lights when power is on.

FREQUENCY switch is used to select the frequency at which the capacitors are to be tested.

GEN LEVEL control is used to adjust the voltage level of the internal generator.

LOG-LIN switch is used to select the type of null indicator display, logarithmic or linear.

DETECTOR SENSITIVITY control adjusts the gain to the internal detector.

DISSIPATION FACTOR dials are the nulling and readout controls for dissipation factor. Note that the dissipation factor depends on frequency. On instruments that have 120 Hz networks, a dissipation scale is marked in red for use at that frequency.

C RANGE dial is the multiplier for the CAPACITANCE dials.

CAPACITANCE dials are the nulling and readout controls for capacitance. The readout is four digits in line with the index. The last two digits are read from the inner slide-wire dial.

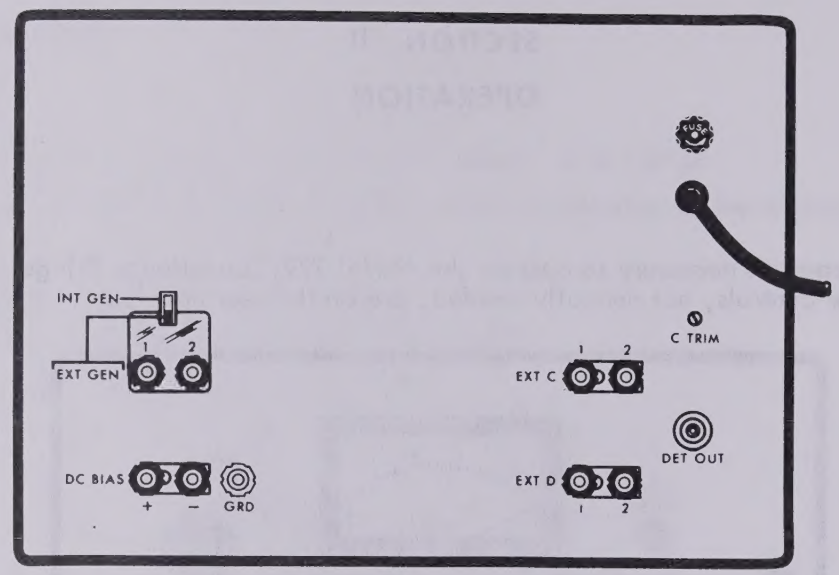


Figure 2-2. Rear Panel

2.1.2 Rear Panel Controls

C TRIM control on the rear of the instrument is used to adjust the value of the standard capacitor. This adjustment should only be made when there is a standard capacitance of known value to calibrate the system. See Section 3.2, ALIGNMENT.

INT GEN switch is used to select internal or external generator for bridge power.

EXT GEN binding posts are used to connect an external generator if it is desired. See Section 2.5, EXTERNAL DETECTOR AND GENERATOR CONNECTIONS.

DC BIAS binding posts are connected in series with the internal generator. These binding posts are used to insert dc bias across the unknown capacitor. The binding posts are normally short-circuited. See Section 2.4, CAPACITANCE MEASUREMENT USING DC BIAS.

EXT C binding posts are connected in series with the CAPACITANCE decade resistance. A resistor can be connected here to extend the capacitance range of the instrument, to compensate for the capacitance of external leads or test fixtures. See Section 2.6, EXTENDED CAPACITANCE AND DISSIPATION FACTOR RANGES. These binding posts are normally short-circuited.

EXT D binding posts are connected in series with the DISSIPATION FACTOR rheostat. A resistor or resistance decade can be connected here to extend the range of the dissipation factor measurements. See Section 2.6. These binding posts are normally short-circuited.

DET OUT connector is an output of the detector amplifier. This output can be used as an oscilloscope input or for other purposes. See Section 2.5.

2.2 BASIC OPERATING PROCEDURE

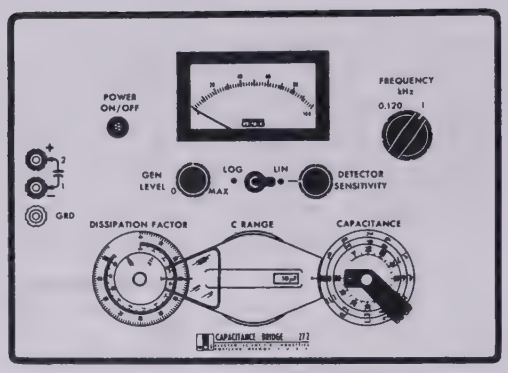


Figure 2-3. Operating Controls

1. Press POWER ON/OFF pushbutton (if it is not lit) to turn on ac power to the instrument.

2. Connect the capacitor to be measured to the binding posts.

3. Set FREQUENCY switch for the frequency needed in the measurement.

   A frequency of 1 kilohertz is normally used for capacitors with values lower than 1 microfarad.

4. Turn GEN LEVEL control fully clockwise.

   This applies a voltage lower than 2 V to the unknown capacitor. If you need a lower voltage, adjust the control while measuring voltage as described in Section 2.9.

5. Set DISSIPATION FACTOR dials to .01 x 10.

   If you know the approximate dissipation factor, set the dials to that setting instead.

6. Set CAPACITANCE dials to 3.000.

   If you know the approximate capacitance of the unknown, set the CAPACITANCE and C RANGE dials to that value instead.

7. Set LOG-LIN switch to LOG and turn DETECTOR SENSITIVITY control so that line on knob lines up with dot at 9 o'clock.

8. Adjust C RANGE dial for minimum indication on the meter

9. Adjust CAPACITANCE and DISSIPATION FACTOR dials alternately for a null on the meter.

   If the CAPACITANCE reading is less than 1.200, set C RANGE dial to the next lower range. If the DISSIPATION FACTOR dial nulls below 10, go to the next lower multiplier setting.

10. Turn the DETECTOR SENSITIVITY control clockwise until meter indication is between 60 and 80 or as high as it will go.

    If the sensitivity is sufficient to distinguish between minor divisions of the CAPACITANCE dial, do not increase the sensitivity.

11. Read the dissipation factor and capacitance directly from the dials.

    If there is some difficulty in balancing the bridge, especially if the dissipation factor is greater than 1, it may be due to a sliding balance. See Section 2.8.

2.3 CONNECTIONS TO UNKNOWN CAPACITORS

2.3.1 Two-Terminal Capacitors

Most capacitors in practical circuits are two-terminal devices. ESI Model 272 Capacitance Bridge is designed to make two- or three-terminal measurements. Figure 2-4 shows connection to a two-terminal capacitor.

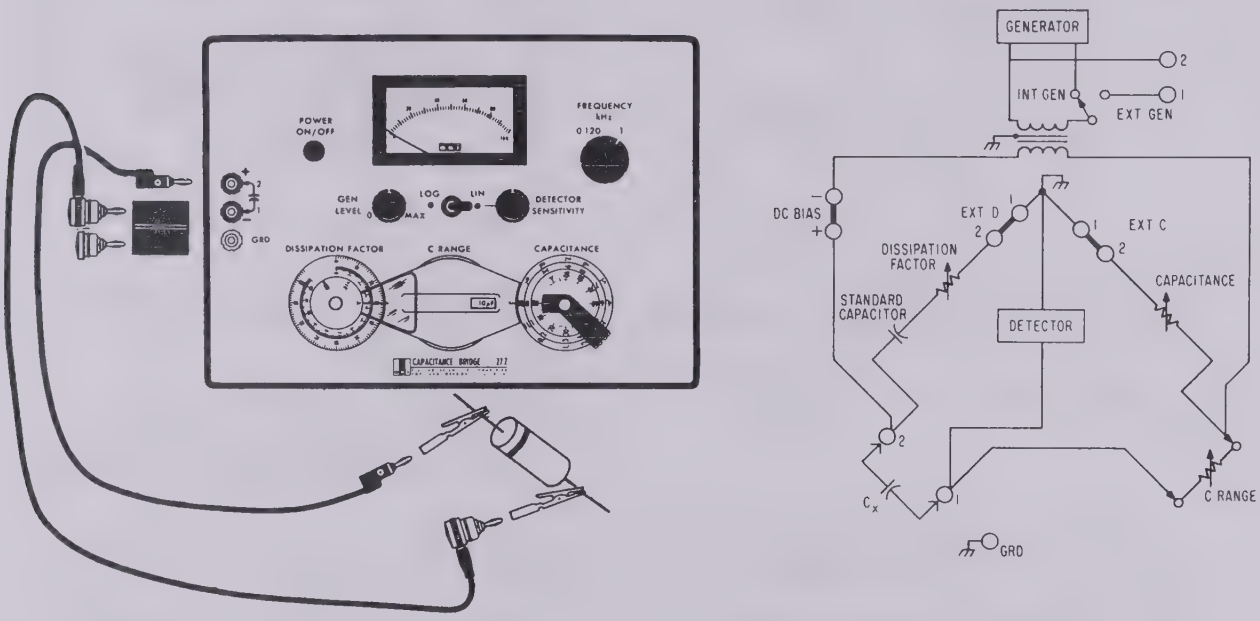


Figure 2-4. Two-Terminal Connection

Many capacitors are designed so that one plate shields the other and is usually grounded. It is not possible to ground either plate of the capacitor being measured with the Model 272 Capacitance Bridge. The lead connected to this plate should connect to binding post 1 of the bridge. Figure 2-4 shows this connection. This connection places the leakage capacitance between the shielding plate and ground across the detector where it will have no effect on the accuracy of the measurement.

2.3.2 Three-Terminal Capacitors

Low-capacitance devices (especially standard capacitors) are designed with three terminals. One terminal is connected to a shield that surrounds the capacitor. ESI Model 272 Capacitance Bridge is designed to measure this type of capacitor with the shield grounded (see Figure 2-5). In this way, the stray capacitance C_a is across the detector and will have almost no effect on the accuracy of the measurement. The stray capacitance C_b is across the standard capacitor and will have negligable effect unless it is higher than 10 picofarads.

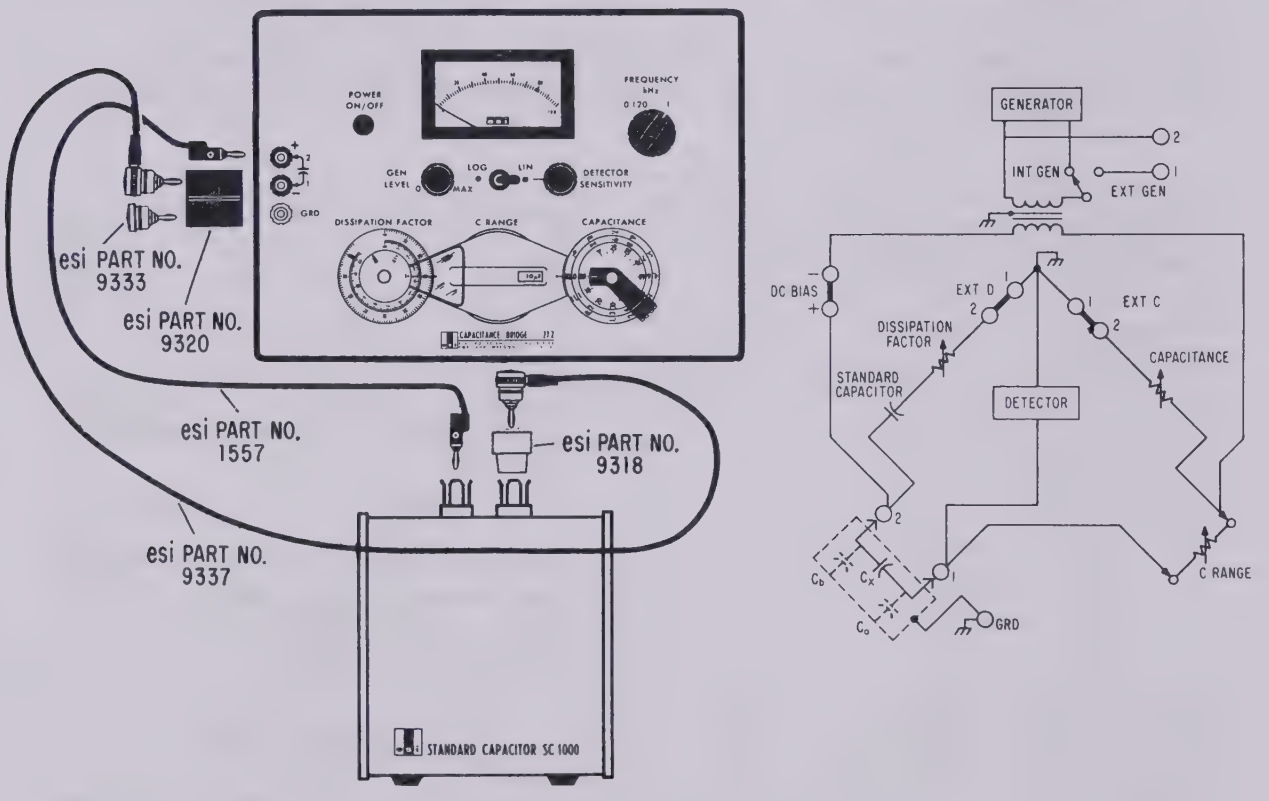


Figure 2-5. Three-Terminal Connection

2.3.3 Notes on Capacitance Measurement

Low-Capacitance Measurements

In making low-capacitance measurements, there are three things to watch out for:

1. Be careful to avoid pickup.
2. Keep the stray capacitance to a minimum.
3. Subtract the zero capacitance of the bridge from the dial reading.

To minimize the first two effects, keep hands as far as possible from the capacitor being measured. The zero capacitance of the bridge is measured with nothing connected to the terminals; it is approximately 2 picofarads.

Keep the leads as short and direct as possible. If extended leads are necessary, the lead from terminal 2 should be shielded.

High-Capacitance Measurements

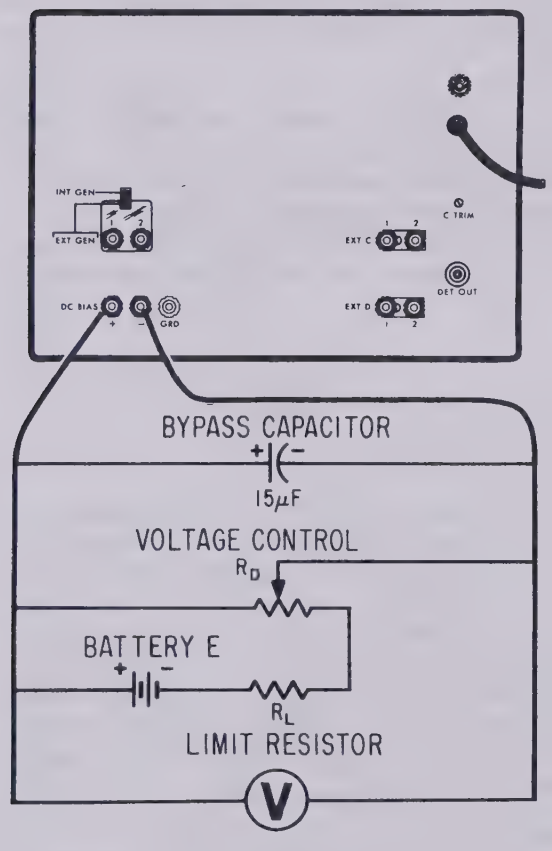
The bridge measures the total impedance connected to its terminals. Both the unknown capacitor and its leads contribute to this impedance. The leads have some resistance and inductance which affect the value read from the bridge. For the greatest accuracy, minimize the lead impedance. Short heavy leads will reduce the resistance and closely spaced, twisted leads will reduce inductance and the pickup of stray fields.

2.4 CAPACITANCE MEASUREMENT USING DC BIAS

The generator voltage of the Model 272 is so low that a dc bias is almost never needed. In some cases, however, capacitors need a polarizing voltage. Electrolytic and tantalum capacitors, for example, may give erroneous readings unless they are biased to prevent polarity reversal during test. Many electrolytic and tantalum capacitors can be damaged by the reverse half-cycle of an alternating current, although not generally by a low voltage level such as that used in the Model 272 Capacitance Bridge.

2.4.1 Battery Bias Supply

The dc bias should be supplied from a power-limited source in order to prevent damage to the bridge in case the unknown capacitor terminals are shorted. The battery supply circuit is shown in Figure 2-6.



SUPPLY VOLTAGE E (VOLTS)	LIMITING RESISTOR R_L (OHMS)	VOLTAGE CONTROL R_D (OHMS)
1	0.27	2
1.5	0.56	5
2	1.0	10
3	2.7	25
4	4.7	40
4.5	5.6	50
6	10	100
9	22	250
12	39	400
15	56	500
22.5	150	1.5k
24	150	1.5k
28	220	2.5k
30	220	2.5k
45	330	3.0k
67.5	1.2k	10k
90	2.2k	20k
103.5	2.7k	30k
120	3.9k	50k
225	13k	100k
300	22k	250k

Figure 2-6. Battery Bias Supply Circuit

The power in the circuit shown is limited to 1 watt by resistor R_L. Values shown are for commonly available voltages. The limiting resistors can have tolerances of 20% and should be rated at 5 watts or more. If the proper value of resistance is not available, use a larger value rather than smaller. The voltage control potentiometer may differ from the listed value by a factor of 2. It should be rated at 1 watt or more.

If a supply voltage much different from those listed is to be used, use the following formula to determine the proper value of limiting resistance:

$$R_L = \frac{E^2}{4}$$

Batteries are recommended because most line-operated power supplies have high leakage capacitance to ground and many have objectionable high dc leakage to ground.

For protection of the standard capacitor, do not use a voltage higher than 500 volts.

2.4.2 Line-Operated Supply

It is possible to use a line-operated power supply to furnish dc bias for the Model 272 Capacitance Bridge if a few precautions are taken. The supply should be isolated from the power line and from ground. The capacitance from any part of the power supply circuit to ground should be less than 100 picofarads.

An isolation transformer and shielding may make it possible to use many commonly available power supplies. The transformer should have a well shielded primary and secondary. The two shields should be separate and the capacitance between them should be low. (See Figure 2-7 for circuit details.) The primary shield should be connected to ground. The capacitance between the shields may be a major part of the capacitance between the power supply circuit and ground. The transformer should, of course, have a high enough power rating to operate the bias supply.

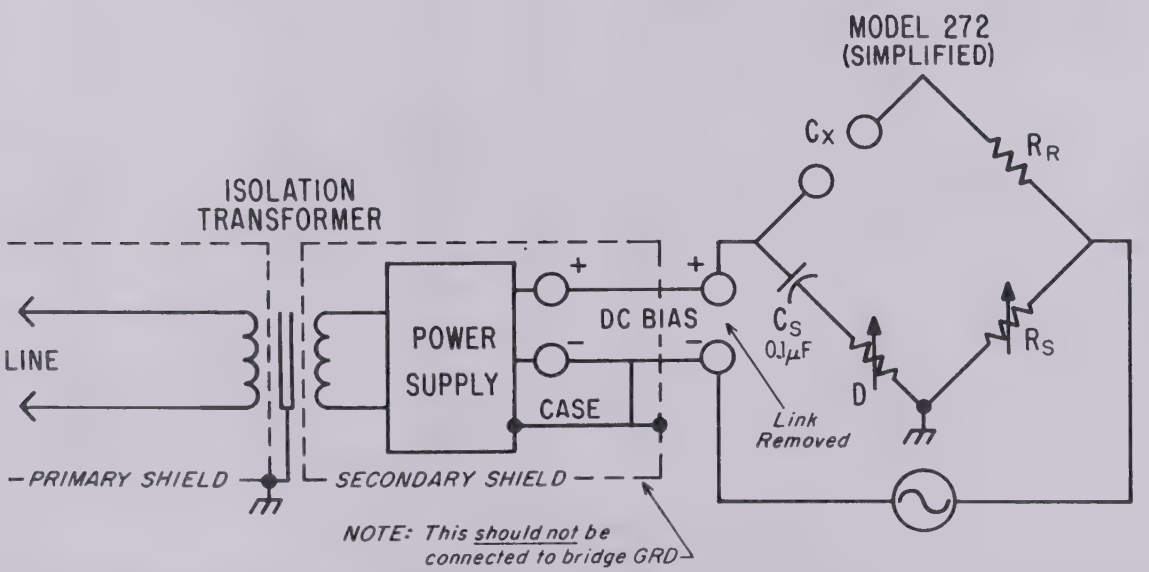
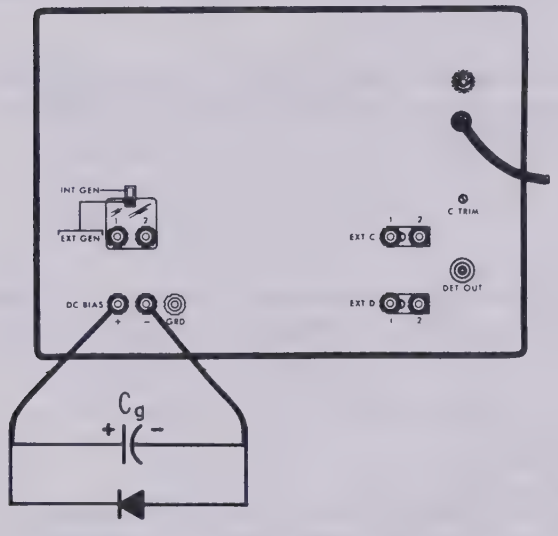


Figure 2-7. Line-Operated Bias Supply

2.4.3 Simple Diode-Capacitor Circuits

In many cases, the actual magnitude of the bias voltage is unimportant, but the magnitude must be high enough to keep the voltage on the capacitor from reversing polarity during the reverse half-cycle. Simple diode-capacitor circuits can be inserted in series with the generator to rectify it and establish a bias level. The simplest of these circuits is a diode and capacitor connected across the DC BIAS binding posts as shown in Figure 2-8. Note that the anode of the diode is connected to the – binding post and the cathode is connected to the + post in order to maintain proper polarity at the binding posts on the front panel.

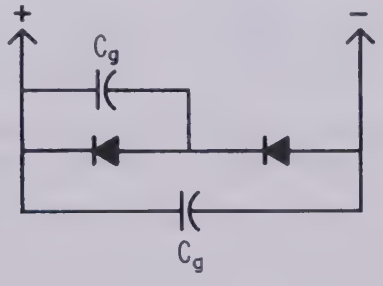


UNKNOWN CAPACITOR			C_g
Less than	0.2	µF	0.56 µF
0.2 to	0.5	µF	0.68 µF
0.5 to	1	µF	0.82 µF
1 to	2	µF	1.5 µF
2 to	5	µF	3.3 µF
5 to	10	µF	5.6 µF
10 to	20	µF	5.6 µF
20 to	50	µF	10 µF
50 to	110	µF	27 µF

Figure 2-8. Diode-Capacitor Bias

Germanium diodes are recommended for this application because they have a lower forward voltage drop. Note that the values of C_g depend on the value of the unknown capacitor. These capacitors can be ±10% components with voltage ratings as low as 1 volt.

The above circuit attenuates the generator ac voltage in order to establish a dc level; the ac voltage across the unknown capacitor is 1/2 to 1/4 the value it would have without the bias circuit. The ac voltage can be increased without decreasing the dc by using a voltage doubler circuit as shown in Figure 2-9. In this case, the capacitors C_g should be approximately equal to the unknown capacitor or to 1 microfarad, whichever is larger.



C_g Approximately Equal to Unknown Capacitor or 1µF, Whichever is Larger

Figure 2-9. Voltage Doubler

2.5 EXTERNAL DETECTOR AND GENERATOR CONNECTIONS

2.5.1 Detector Output

The DET OUT socket on the rear panel is a BNC-type connector that provides an amplified voltage of the same frequency as the detector input and a magnitude proportional to the front-panel meter reading. The magnitude is approximately 0.3 volts for full-scale indication and is linear (if the LOG-LIN switch is set to LIN) for approximately 5 times the full-scale meter indication.

When the LOG-LIN switch is set to LOG, the output waveform is distorted to give a magnitude that varies logarithmically with the input.

The output voltage is in series with a 10-kilohm resistance which limits the output current. This resistance will have no effect on oscilloscope displays or high-impedance voltmeter readings, since they are typically more than 10 megohms.

2.5.2 External Detector

There are no external terminals specifically for connecting an external detector. It is quite simple, however, to connect an external detector; connect it between binding post 1 and ground.

2.5.3 External Generator

EXT GEN binding posts on the rear of the instrument connect to an isolation transformer when the rear panel switch is in the EXT GEN position. Because of this, the external generator can be grounded at EXT GEN binding post 2 without causing ground loops or measurement errors. The input voltage should be limited to 100 volts or 160 times the generator frequency in kilohertz, whichever is less. Higher voltages will saturate the isolation transformer and will be distorted. A few examples are shown in the following table:

FREQUENCY	MAXIMUM VOLTAGE
50 Hz	8 V
60 Hz	10 V
100 Hz	16 V
120 Hz	20 V
400 Hz	65 V
1000 Hz and Higher	100 V

The isolation transformer steps the input voltage down a factor of approximately 3.5. The voltage across the bridge will be that much less than the input to the isolation transformer.

The input power should be limited to one watt. This can be done easily by inserting a resistor in series with the generator (see Figure 2-10). The resistors used can have tolerances of 10 or 20 percent and should be rated at 5 watts or more. If the proper value of resistance

is not available, use a larger value rather than a smaller. Note that the voltage limits of the isolation transformer apply only to the voltage between the binding posts. A power-limiting resistor will drop some voltage and so the generator voltage can be higher than the voltage at the binding posts.

If a supply voltage much different from those listed is to be used, calculate the value of the limiting resistor from the formula:

$$R_L = \frac{E^2}{4}$$

If the voltage is less than 15 volts, no power limiting is necessary.

SUPPLY VOLTAGE (VOLTS)	R_L (OHMS)
15	56
20	100
30	220
50	680
100	2700

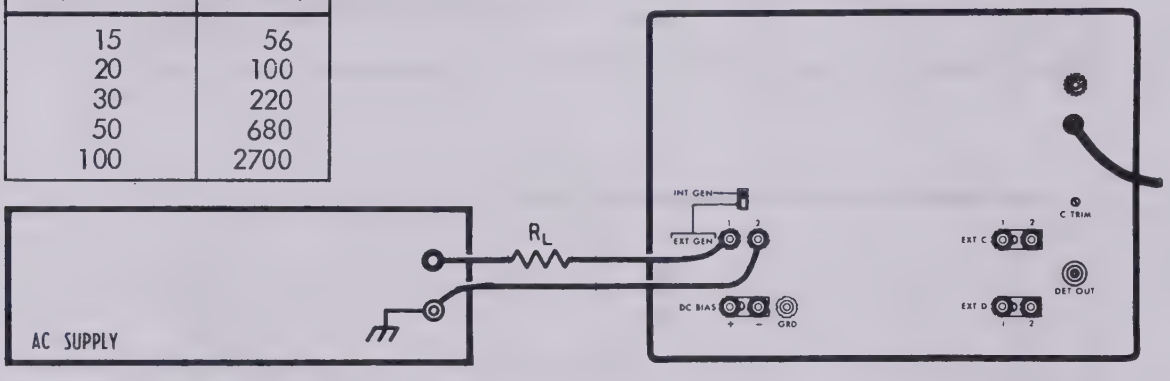


Figure 2-10. External Generator

2.6 EXTENDED CAPACITANCE AND DISSIPATION FACTOR RANGES

The resolution and range of capacitance and dissipation factor measured by the bridge can be extended by connecting external resistances (usually decade resistors) to the terminals provided. (See Figure 2-11). The external resistances and the front panel dials are used to balance the bridge and capacitance and dissipation factor can be calculated as follows:

$$C = C_R (10R_c + C_{dial})$$

$$D = f_k (0.682\ R_D + D_{dial})$$

C is the capacitance.

D is the dissipation factor.

C_R is the C RANGE setting.

f_k is the frequency in kilohertz.

R_c is the resistance of the external C rheostat in kilohms.

R_D is the resistance of the external D rheostat in kilohms.

C_{dial} is the CAPACITANCE dial reading.

D_{dial} is the DISSIPATION FACTOR (black scale) dial reading.

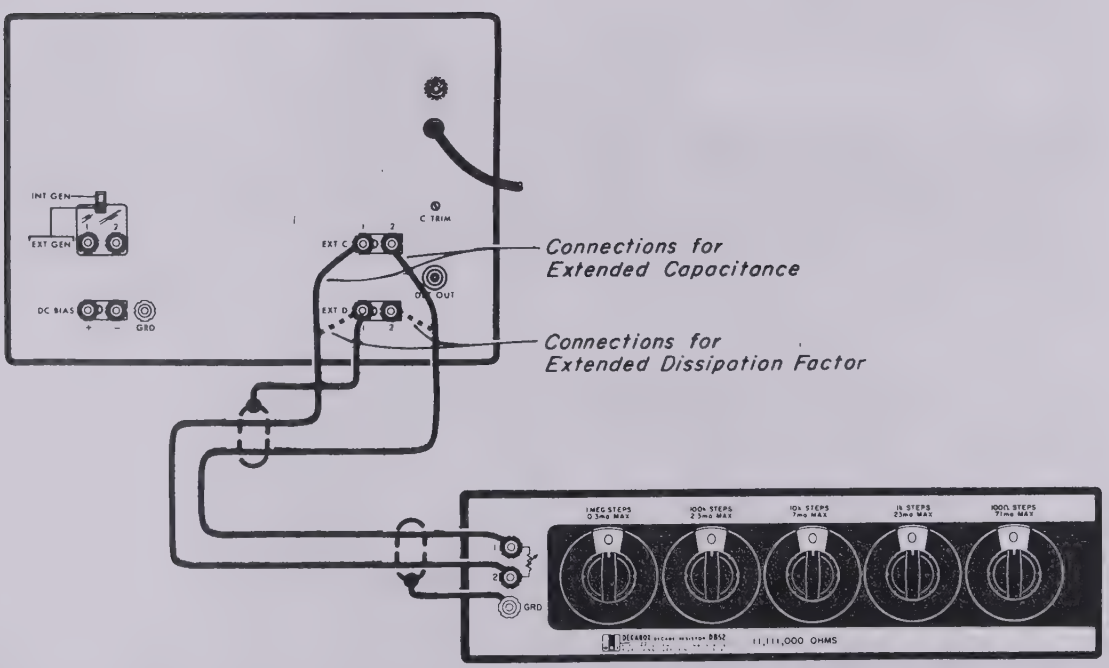


Figure 2-11. Extended Capacitance and Dissipation Factor

2.7 OPERATION AT NON-STANDARD FREQUENCIES

Standard frequencies of the bridge are 1 kilohertz and 120 hertz or 100 hertz. Three additional frequencies can be added to the instrument (we recommend that the modification be done at the factory) or an external generator and detector can be used.

Accuracy of the bridge decreases at higher frequencies. Operation of the bridge at frequencies higher than 10 kilohertz is not recommended. Figure 2-12 shows accuracy of the bridge at some frequencies.

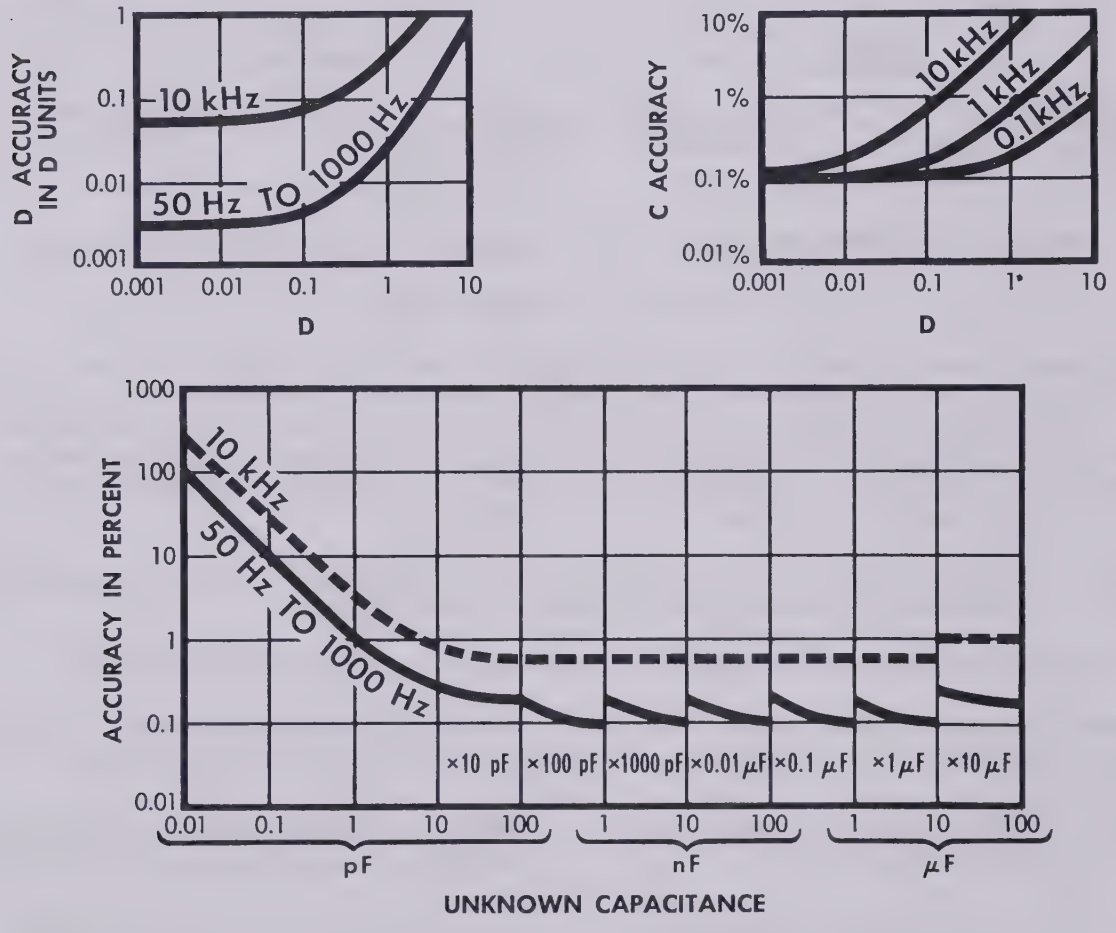


Figure 2-12. Accuracy For Different Frequencies

The dissipation factor measured by the bridge does not read directly from the dials at any frequencies other than 1 kilohertz (black dial) and 120 hertz (red dial). For other frequencies, multiply the black dial reading by the frequency in kilohertz.

2.8 SLIDING BALANCE

When lossy capacitors are measured, the nulling problem known as sliding balance can occur. It is not too serious if the D of a capacitor is less than 1, in which case an external D rheostat may be necessary.

The problem becomes apparent when the instrument seems to have false nulls at different settings of the CAPACITANCE dials and the DISSIPATION FACTOR dial. Figure 2-13 illustrates the cause of the difficulty.

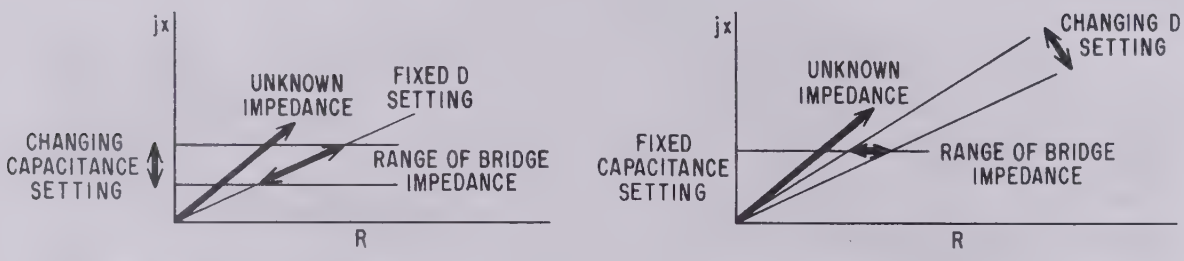


Figure 2-13. Sliding Balance

If the unknown impedance and the bridge impedance are considered as vectors, the bridge is balanced when the vectors are equal. The CAPACITANCE decade dials change the vector of the bridge impedance only along the R axis, and the DISSIPATION FACTOR dial changes the angle of the vector of the bridge impedance. If the angle of the unknown impedance vector is not steep, the CAPACITANCE decades and the DISSIPATION FACTOR dial operate nearly perpendicular to each other and there is little or no difficulty.

If the D of a capacitor is high, the vector of the unknown impedance has such a steep angle that the dials no longer move the bridge impedance vector directly to a null.

The following technique will allow rapid and accurate measurements with sliding balance.

1. Make a preliminary measurement using the techniques described in Section 2.2	This gives a first approximation. The null at this point may not be very sharp.
2. Adjust DETECTOR SENSITIVITY control so that meter pointer is on 60.	This sets a reference level on the detector. As the null comes closer, use marks closer to 0.
3. Turn the inner CAPACITANCE dial a small amount in one direction, then adjust DISSIPATION FACTOR dial for minimum detector deflection.	Turn one switch step of the outer dial at first. Use smaller steps when the null is close.

4. Note the reading on the meter. If it is closer to 0, repeat steps 2 and 3, turning CAPACITANCE dial in the same direction. If the reading is further from 0, repeat steps 2 and 3, turning CAPACITANCE dial in the opposite direction.

5. When the null is close, turn the DISSIPATION FACTOR dial part of a dial division at a time and adjust CAPACITANCE dial for best null.

This procedure should converge to a sharp null. Each step should be shorter than the last when the null is close.

2.9 VOLTAGE ACROSS THE UNKNOWN CAPACITOR

In many cases, it is necessary to know the ac voltage across the unknown capacitor. To measure this voltage, connect a high-impedance ac voltmeter between the DC BIAS + binding post and the GRD binding post. Balance the bridge first and then read the ac voltage. This method does not load the unknown capacitor with the impedance of the voltmeter, but the voltmeter is shunted across the standard capacitor. For this reason, the voltage across the capacitor will be correct, but the value of capacitance may not. For the correct capacitance reading, disconnect the voltmeter and rebalance the bridge.

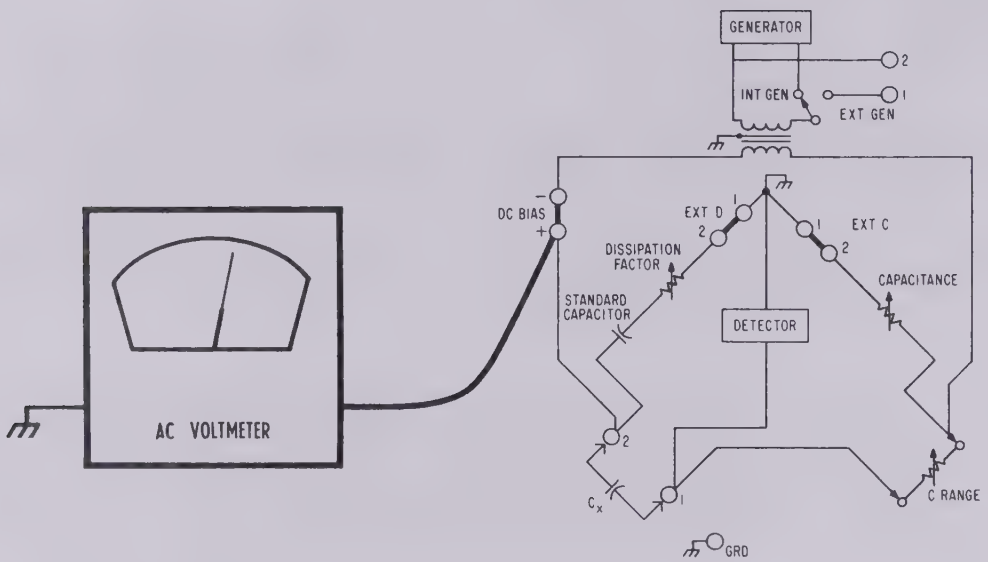


Figure 2-14. Voltage Across Unknown Capacitor

2.10 EQUIVALENT CIRCUIT IMPEDANCE

The bridge indication is of a simple equivalent circuit consisting of a capacitor in series with a resistor. An alternate presentation of the same impedance would be of a different capacitance and resistance in parallel. The phase and magnitude of the measured impedance would be the same for both circuits. The following formulas can be used to determine equivalent circuit elements:

$$Z = \frac{D - j}{2\pi f C_s}$$

$$R_s = \frac{D}{2\pi f C_s}$$

$$C_p = \frac{C_s}{1 + D^2}$$

$$R_p = \frac{1}{2\pi D f C_p}$$

C_s is measured series capacitance in microfarads.

D is measured dissipation factor.

f is frequency in kilohertz.

$j = \sqrt{-1}$.

Z is measured impedance in kilohms (complex number).

R_s is equivalent series resistance in kilohms.

C_p is equivalent parallel capacitance in microfarads.

R_p is equivalent parallel resistance in kilohms.

SECTION III

MAINTENANCE

3.1 COMPONENT ACCESS

3.1.1 Removing Outer Case

Prepare a soft, clean place to set the instrument. Be sure that no projections or pointed objects will be underneath it. See that there are no metal filings in the area.

The upper and lower halves of the outer case can be removed separately. To remove either, remove two bolts on each side and slide cover straight off. Be careful to avoid damage to components.

3.1.2 Removing Circuit Boards

Remove upper half of case for access to circuit boards. Be sure POWER switch is set to OFF. Grip circuit boards firmly and lift *straight* out of plugs. Remove the four connectors from face of detector board before removing it.

3.2 PERIODIC MAINTENANCE

The following procedures should be performed periodically (approximately once a year) to insure maximum accuracy and reliability from the Model 272 Capacitance Bridge.

If problems can be isolated to individual parts, the defective part should be returned to the factory for repair or replacement. If the need for major repairs is apparent, it is recommended that the unit be sent to the factory for service. The service department will be happy to furnish the necessary information for repairs as well as any replacement parts. However, unauthorized repairs will invalidate the instrument warranty.

3.2.1 Visual Inspection

Remove upper and lower halves of outer case, as described in Paragraph 3.1.1. Inspect the outside of the unit for dial orientation and damage to connectors, binding posts, and binding post caps. Check for dirt around binding post insulators. Inspect the interior of the unit for loose or broken connections, damaged or dirty switch or socket contacts, heat-damaged resistors, and resistors touching each other or the grounded switch structure.

3.2.2 Cleaning and Lubrication

Clean the front panel with a soft, dry, lint-free cloth, being particularly careful to remove all dirt from around binding post insulators.

The only internal components that may require cleaning and lubrication are the rotary switches. These are carefully lubricated at the time of manufacture and are protected by the instrument case. They should rarely, if ever, require maintenance. It is recommended that they be cleaned and lubricated *only* if they are not making good electrical contact. Proceed as follows:

1. Place instrument horizontally on bench, with a sheet of white paper under switch to be cleaned. Spray switch with Freon TF degreaser in aerosol can (Miller Stephenson Co. or equivalent) until no more dirt appears on paper. Drying is not necessary.
2. Lubricate with a low-conductivity oil (Viscosity Oil Co. No. 7069, available from ESI as Part No. 13500). Apply one drop to each rotor tab and one drop to the rotor ring contact, using a hypodermic needle. With a small brush, apply a dab of petroleum jelly to each switch bearing and detent mechanism. DO NOT OVERLUBRICATE.

3.2.3 Replacing Outer Case

Be sure the interior of the case is completely clear of all foreign material. Slip case over unit and replace the bolts.

3.3 ALIGNMENT

Do not perform the alignment procedures unless a properly calibrated standard capacitor is available.

3.3.1 Equipment Required

Standard Capacitor: 0.1 μF ±0.1%; calibration accuracy ±0.02% at 1 kHz and with two-terminal measurement.

Recommended Type: General Radio 1409-T

3.3.2 Connection

Connect the standard capacitor to the connection device that is normally used with the bridge. For example, if the cable set supplied is to be used normally, connect it to the standard capacitor. If a component-holding device is normally used, use short bare wires connected to the standard (if necessary) to simulate component leads.

Connect the case and the low (outer foil) terminals of the standard together. A short lug is provided with the recommended standard capacitor to connect the L and G terminals. In this way, the capacitor is operating as a two-terminal device. Connect this low terminal to terminal 1 of the bridge. Connect terminal 2 of bridge to the high terminal of the standard capacitor.

3.3.3 Alignment Procedure

1. Connect the standard capacitor to the bridge as described above and turn on bridge power.
2. Set CAPACITANCE dial to calibrated (two-terminal) value of the standard.
3. Adjust C TRIM control at rear of instrument (with screwdriver) and DISSIPATION FACTOR dial for null indication.

3.4 PARTS LIST

The following parts list is in alpha-numerical order of the circuit reference designator. Miscellaneous parts are included at the end of the list. Manufacturer of the part is given in a code number according to the Federal Supply Code for Manufacturers (see list of manufacturers below).

Parts manufactured by Electro Scientific Industries must be ordered from the factory. When ordering, include the following information:

Model and serial number of the instrument
Electro Scientific Industries part number
Circuit reference designator
Description of part

CODE LIST OF MANUFACTURERS

01121	ALLEN BRADLEY COMPANY, Milwaukee, Wisconsin
11837	ELECTRO SCIENTIFIC INDUSTRIES, INC., Portland, Oregon
13511	BUNKER-RAMO CORPORATION, Amphenol Connector Division, Los Gatos, California
56289	SPRAGUE ELECTRIC COMPANY, North Adams, Massachusetts
65029	WESTON INSTRUMENTS, Division of Daystrom, Inc., Newark, New Jersey
75915	LITTELFUSE, INC., Des Plaines, Illinois
76854	OAK MANUFACTURING COMPANY, Crystal Lake, Illinois
95146	ALCO ELECTRONICS PRODUCTS, INC., Lawrence, Massachusetts

CKT REF	DESCRIPTION	MFR CODE	MFR PART NUMBER	ESI PART NUMBER	QTY USED
A1	Printed Circuit Board Assembly, Power	11837		18791	1
A2	Printed Circuit Board Assembly, Oscillator	11837		18794	1
A3	Printed Circuit Board Assembly, Detector	11837		18789	1
C1, R11-R13	Triplestat Assembly	11837		20358	1
C2-C8, R2-R8	Range Switch Assembly	11837		20357	1
C9	Capacitor, Trimmer			18642	1
C20, C21	Capacitor, 0.01 μF, 1000 V	56289	41C121A1	1918	2
F1	Fuse, 1/2 A	75915		1802	1
M1	Meter	65092	1939	9167	1
R1, S6, S7	Dekastat Assembly	11837		18793	1
R14	Potentiometer, 10 kΩ	01121	JA1N300P500UA	18747	1
R15	Potentiometer, 50 Ω	01121	JA1N300P103AA	18746	1
R50	Resistor, 47 kΩ, 1/4 W, 10%	01121	CB4731	13941	1
S1	Switch, ON/OFF, with Lamp	76854	616-6-1-A1H	18418	1
S2	Switch, SPDT	95146	MST-115D	18769	1
S3, R100-R105	Switch Assembly, Frequency Range	11837		18775	1
	120-Hz Network Assembly	11837		18826	1
	1-kHz Network Assembly	11837		18828	1
S4	Switch, Slide, DPDT	76854	339278-278	13349	1
T1	Transformer, Power	11837		18767	1
T2	Transformer, Output	11837		18725	1

DESCRIPTION	MFR CODE	MFR PART NUMBER	ESI PART NUMBER	QTY USED
Binding Post	11837		1475	12
Binding Post Cap	11837		1476	10
Binding Post Cap, Gold	11837		1172	2
Button Bushing	11837		75877	1
Cable Set	11837		2863	1
Coaxial Connector, BNC	13511	31-102	13255	1
Connector, 15-Pin, PCB	13511	255-21511-101	13686	2
Dial	11837		4775	1
Dial	11837		73044	1
Dial, 0.-11.	11837		75292	1
Dial, "D"	11837		18734	1
Dial, "D" Range	11837		20347	1
Dial, Range	11837		18738	1
Foot, Large Rubber	11837		8715	2
Index	11837		73019	1
Index Bracket	11837		4481	1
Indicator	11837		18733	1
Instruction	11837		20355	1
Knob, Large Bar	11837		1458	1
Knob, Small Round	11837		1472	2
Nylon Bearing	11837		2799	1
Spacer	11837		2678	4
Split Bushing	11837		5282	1
Split Bushing	11837		5289	1
Swing Lug	11837		3247	3

3.5 SCHEMATIC DIAGRAMS

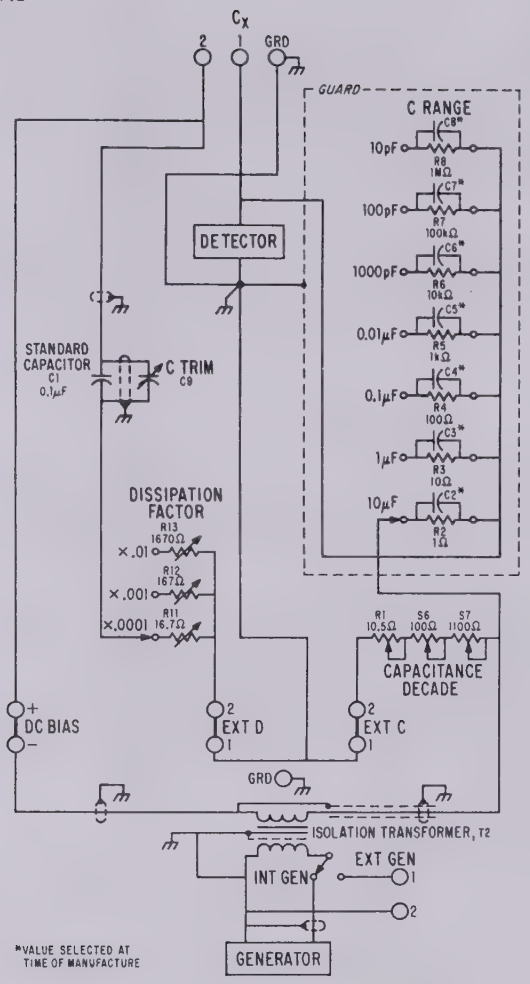


Figure 3-1. Model 272 Bridge Circuit

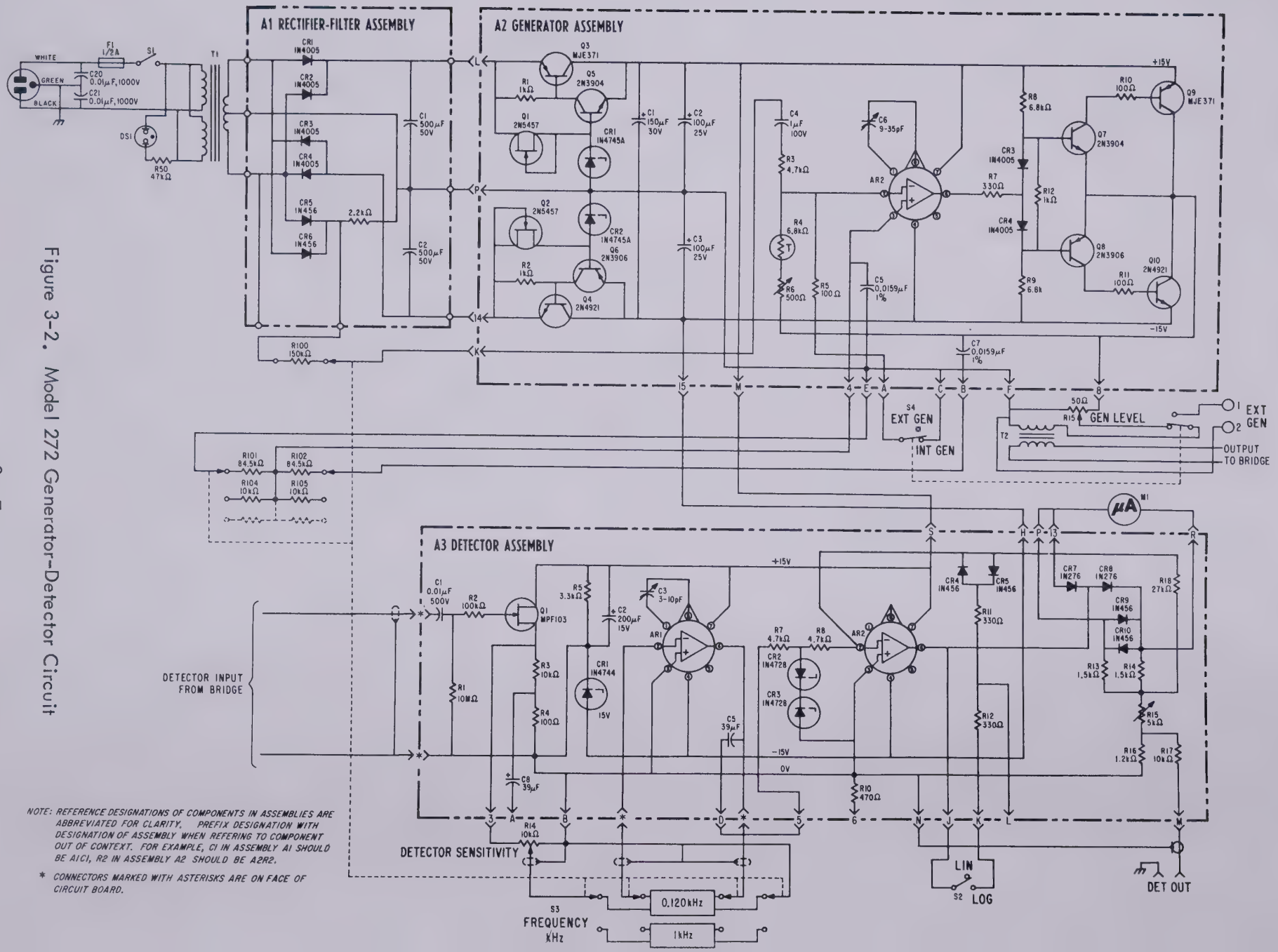


Figure 3-2. Model 272 Generator-Detector Circuit

NOTE: REFERENCE DESIGNATIONS OF COMPONENTS IN ASSEMBLIES ARE ABBREVIATED FOR CLARITY. PREFIX DESIGNATION WITH DESIGNATION OF ASSEMBLY WHEN REFERING TO COMPONENT OUT OF CONTEXT. FOR EXAMPLE, C1 IN ASSEMBLY A1 SHOULD BE A1C1, R2 IN ASSEMBLY A2 SHOULD BE A2R2.

* CONNECTORS MARKED WITH ASTERISKS ARE ON FACE OF CIRCUIT BOARD.

WARRANTY OF QUALITY

Electro Scientific Industries, Inc. warrants its products to be free from defects in material and workmanship for the following periods:

1. Two years for components and instruments using passive circuitry. One year for repairs of out-of-warranty items.
2. One year for components and instruments using active circuitry (see ESI Metrology Catalog). Six months for repairs of out-of-warranty items.

During the in-warranty periods, we will service or, at our option, replace any device that fails in normal use to meet its published specifications. Batteries, tubes and relays that have given normal service are excepted.

WARRANTY OF TRACEABILITY

Electro Scientific Industries, Inc. maintains reference standards of measurement which are compared with the U. S. National Standards through frequent tests by the U. S. National Bureau of Standards.

ESI working standards and testing apparatus used are calibrated against the ESI reference standards in a rigorously maintained program of measurement control.

The manufacture and final calibration of all ESI instruments are controlled by use of the ESI reference and working standards and testing apparatus in accordance with established procedures and documented results. (Reference MIL-C-45662)

Final calibration of this instrument was performed with reference to the mean values of the ESI reference standards or to ratio devices that were verified at the time and place of use.

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13900 N.W. SCIENCE PARK DRIVE / PORTLAND, OREGON 97229 / U.S.A.
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